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A $^{40}Ar/^{39}Ar$ dating study of very low-grade metamorphism from the Rybachi and Sredni Peninsulas, NW Russia - a preliminary report

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REPORT

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Title:

A $^{40}Ar/^{39}Ar$ dating study of very low-grade metamorphism from the Rybachi and Sredni Peninsulas, NW Russia – a preliminary report

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Summary:

$^{40}Ar/^{39}Ar$ step-heating analyses carried out on Neoproterozoic, cleaved pelites from the Rybachi Peninsula, Kola, Northwest Russia, were not definitive in terms of trying to date the pervasive, syn-folding metamorphic event. Spectra from all six samples are consistent with mixtures of detrital phyllosilicates and authigenic illite. The highest, integrated, total fusion ages are from diagenesis-grade rocks in the southwestern part of Rybachi, whereas the lowest total fusion ages are from the anchizone-grade rocks in the northeast.

The detrital end-members in the mixtures appear to have a minimum age of 850-900 Ma. This age is similar to that generated from detrital grains in a Rb-Sr study of illites from shales on the neighbouring Sredni Peninsula, and also from the Varanger Peninsula in Norway. The low-T increment in the gas-release spectra falls in the range 350-400 Ma, an age which is comparable to $^{40}Ar/^{39}Ar$ mineral isochron, thermal overprint ages (373-401 Ma) from dolerite dykes cutting cleaved shales on Rybachi. These low-T dates may be ascribed to the thermal influence of burial by an originally thick and widespread cover of Upper Devonian-Carboniferous sedimentary rocks in this and adjacent regions of NW Russia and the southern Barents Sea.

Keywords: Aldersbestemmelse	Senproterozoikum	Kolahalvøya
Lavgrads omdannelse	Baikalsk omdannelse	

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1. INTRODUCTION

On the Kola Peninsula of Northwest Russia, Neoproterozoic sedimentary successions unconformably overlie Archaean and Paleoproterozoic metamorphic complexes in several areas along the northern and southern coasts. Along the northern, Barents Sea coastline, such successions are particularly well exposed on the Rybachi and Sredni Peninsulas and Kildin Island (Lyubtsov et al. 1990). Lithostratigraphies comparable to those on Rybachi and Sredni also occur on the Varanger Peninsula in NE Norway (Siedlecka et al. 1995a, b). In both these areas – Varanger and Rybachi-Sredni – a major, long-lived, NW-SE-trending fault zone separates a coastal-shelf, ***pericratonic***, sedimentation domain from an active continental-slope, ***basinal*** domain (Siedlecka & Roberts 1993). These disparate domains can be followed southeastwards into northeasternmost Kola and then, partly with the help of geophysical data, into the Kanin Peninsula and the Timans (Olovyanishnikov et al. 1998) on the southwestern side of the Pechora Basin. The entire, 1800 km-long, bipartite belt, situated along the northeastern margin of the Fennoscandian Shield and Russian Platform, is referred to as the *Timan-Varanger Belt* (Olovyanishnikov et al. 1997).

Tectonic deformation and metamorphism of these Late Riphean to (partly) Early Vendian successions in the Timans, Kanin and Rybachi-Sredni are in many ways comparable, involving basinal inversion, SW-directed, compressional fold deformation and generally very low-grade metamorphism. This is what Russian workers have termed the *Baikalian orogeny* (Tschernyschev 1901, Schatsky 1935, 1958), which is broadly equivalent, temporally, to the *Cadomian* of Central and western Europe. In the Timans, K-Ar dating has placed the principal phase of the Baikalian in the time period c. 595-575 Ma (Malkov 1992, recalculated ages), but there has been no specific attempt to date the penetrative cleavage in this region.

On the Rybachi and Sredni Peninsulas of northern Kola, age constraints on the folding and associated cleavage are rather more indirect, and fall in the broad time range c. 610-546 Ma (Roberts 1995). Using illite separates from an earlier study of the very low-grade metamorphism on Rybachi and, in part, Sredni (Rice & Roberts 1995), we therefore decided to try to generate a more precise date for this penetrative metamorphic event employing the ^{40}Ar-^{39}Ar method. In this brief report, we present the main results of this investigation.

2. REGIONAL SETTING

Modern descriptions of the Late Riphean lithostratigraphic successions occurring on Rybachi and Sredni (Fig. 1) can be found in Siedlecka et al. (1995a, b). Principal features of the structural geology are given in Roberts (1995) and Roberts & Karpuz (1995), while a study of the illite crystallinity and very low-grade metamorphism has been reported by Rice & Roberts

(1995). A major, NW-SE-trending, complex fault zone separates the two peninsulas, but it also cuts through the southernmost part of Rybachi (Fig. 1). This is the Sredni-Rybachi Fault Zone (SRFZ). This major geofracture separates the pericratonic and basinal domains, to the northeast (Rybachi) and southwest (Sredni), respectively. This is taken to be the same fault structure as that occurring on the Varanger Peninsula in Norway, the Trollfjorden-Komagelva Fault Zone (TKFZ), e.g. Karpuz et al. (1993).

On Rybachi Peninsula, the generally NE-dipping formations (Fig.1) are deformed by NW-SE-trending, open to tight, mesoscopic and larger asymmetric folds. These face southwest and, in pelitic units, carry a pervasive, axial-surface, slaty cleavage dipping steeply northeast. In more silty or sandy lithologies this is a tightly spaced, domainal but continuous cleavage (Roberts 1995). An illite crystallinity study of the pelites indicated a mainly anchizonal grade of metamorphism (Rice & Roberts 1995). On Sredni, the lithologies are generally devoid of any pervasive cross-cutting cleavage, except close to the SRFZ. On the other hand, a bedding-parallel compactional cleavage is well developed in all pelitic units. Along the SRFZ, the early, fold-related cleavage is disrupted by many, anastomosing fault surfaces in a c. 150 m-wide zone, and later, open, south-facing mesoscopic folds (postdating cleavage) are common. These c. E-W folds, and other meso- and microstructures, provide evidence of dextral strike-slip movement (Roberts 1995) along the fault after the synmetamorphic basin inversion episode.

Dolerite dykes transect the folds and cleavage in NW Rybachi at high angles. A $^{40}Ar/^{39}Ar$ laser microprobe study on these dykes yielded no definitive crystallisation age; but they are older than a Mid Ordovician model age (Roberts & Onstott 1995), and they were affected by a very low-grade, Late Devonian/Early Carboniferous thermal event. Paleomagnetic data suggested a Late Vendian to Cambrian intrusive age for these same dykes (Torsvik et al. 1995). On Sredni, one solitary dolerite dyke has given a minimum $^{40}Ar/^{39}Ar$ isochron age of 546 ± 4 Ma. This cuts the compactional diagenetic fabric which has been dated by Rb-Sr on illite to 610-620 Ma (Gorokhov et al. 1995). Also on Sredni, a second generation of authigenic illite, in shales close to the SRFZ, yielded a Rb-Sr maximum age of 570 Ma (Gorokhov et al. 1995). This has been interpreted to possibly reflect either the basin inversion event or the end stage of this synmetamorphic inversion (Roberts 1996). The available age constraints for the folding and cleavage on Rybachi/Sredni, as noted earlier, thus fall within the time range 610-546 Ma.

The penetrative, NW-SE-trending folds and cleavage occurring on Rybachi can also be traced across to the eastern part of the Barents Sea Region of Varanger Peninsula, i.e. the area northeast of the TKFZ (Roberts 1995, 1996, Gjelsvik 1998, Roberts & Walker 1998). Farther to the northwest, these structures are overprinted by gradually more intense ENE-WSW to NE-SW-trending Caledonian folds and cleavage (Roberts 1972, Siedlecki 1980, Rice et al. 1989).

3. $^{40}Ar/^{39}Ar$ PROCEDURES

The illite separates analysed were those used in the earlier investigation of the very low-grade metamorphism, and the sample numbers quoted here are the same as in that study (Rice & Roberts 1995) (Fig. 1). An illite grain size fraction of $\leq$ 2 μm was used for the study. Separation was by disc milling for 30-45 seconds and then by centrifugation, using a modified version of Stokes' Law, first to separate the >2 μm fraction and later to sediment the <2 μm material. Further details are given in Rice & Roberts (1995).

The $^{40}Ar/^{39}Ar$ analyses were carried out at the Université de Lausanne. Samples together with the standards were irradiated for 40 MWH in the central thimble position of the US geological Survey Triga reactor (Dalrymple et al. 1981). All analyses were made using a low blank, double vacuum resistance furnace and metal extraction line connected to a MAP 215-50 mass spectrometer using an electron multiplier. The samples were incrementally heated in the furnace and the gas was expanded and purified using activated Zr/Ti/Al getters and a metal cold finger maintained at liquid nitrogen temperatures. Time zero regressions were fitted to data collected from eight scans over the mass range 40 to 36. Peak heights above backgrounds were corrected for mass discrimination, isotopic decay and interfering Ca-, K- and Cl-derived isotopes of Ar. Blanks were measured and subtracted from the sample signal. For mass 40, blank values ranged from 4×10^{-16} moles at 800 °C to 8×10^{-15} moles at 1500°C. Blank values for masses 36-39 were below 3×10^{-17} moles for all temperatures.

Isotopic production ratios for the Triga reactor were determined from analyses of irradiated CaF_2 and K_2SO_4, and the following values have been used in the calculations: $^{36}Ar/^{37}Ar$ (Ca) = 0.000264 $\pm$ 0.0000017; $^{39}Ar/^{37}Ar$ (Ca) = 0.000673 $\pm$ 0.0000037; and $^{40}Ar/^{39}Ar$ (K) = 0.00086 $\pm$ 0.00023. Correction for the neutron flux was determined using the standard MMHB-1, assuming an age of 520.4 Ma (Samson & Alexander 1987). All samples have a J value of 0.009455 with with an intralaboratory precision of 0.50%. A mass discrimination correction of 1.008 amu was determined by online measurement of air and was applied to the data.

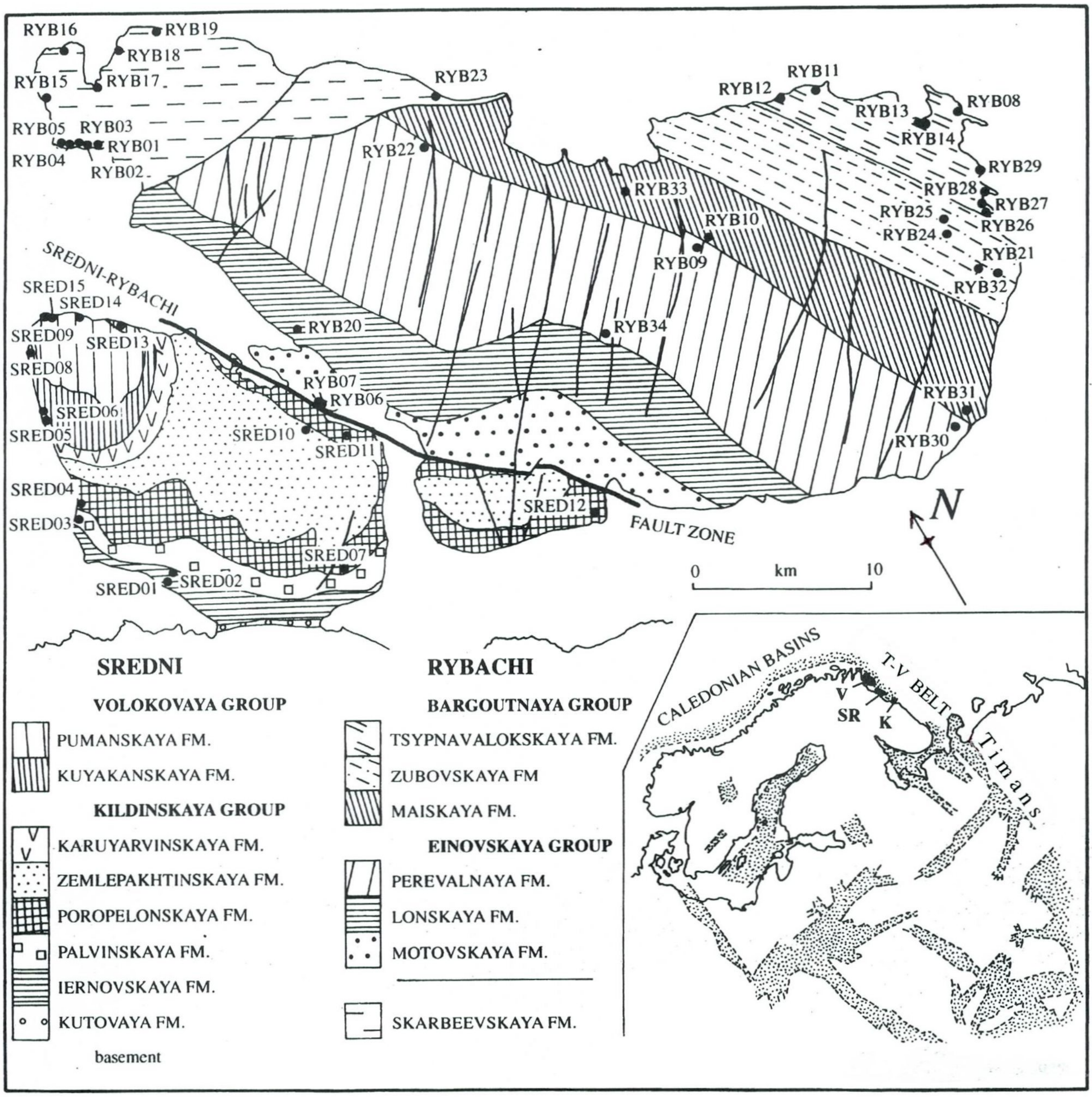


Fig. 1. Geological map of the Rybachi and Sredni Peninsulas showing the sample localities for the earlier study of the very low-grade metamorphism (Rice & Roberts 1995). The figure is taken, and slightly modified from this 1995 paper. The localities of the six samples used in this $^{40}Ar/^{39}Ar$ investigation are all in the northeastern part of Rybachi Peninsula. The inset map (modified from Kumpulainen & Nystuen 1985) shows the network of Neoproterozoic basins (stippled) within the Fennoscandian Shield and Russian Platform. V -- Varanger; SR -- Sredni and Rybachi; K -- Kildin Island; T-V Belt – Timan-Varanger Belt (Basin).

4. RESULTS

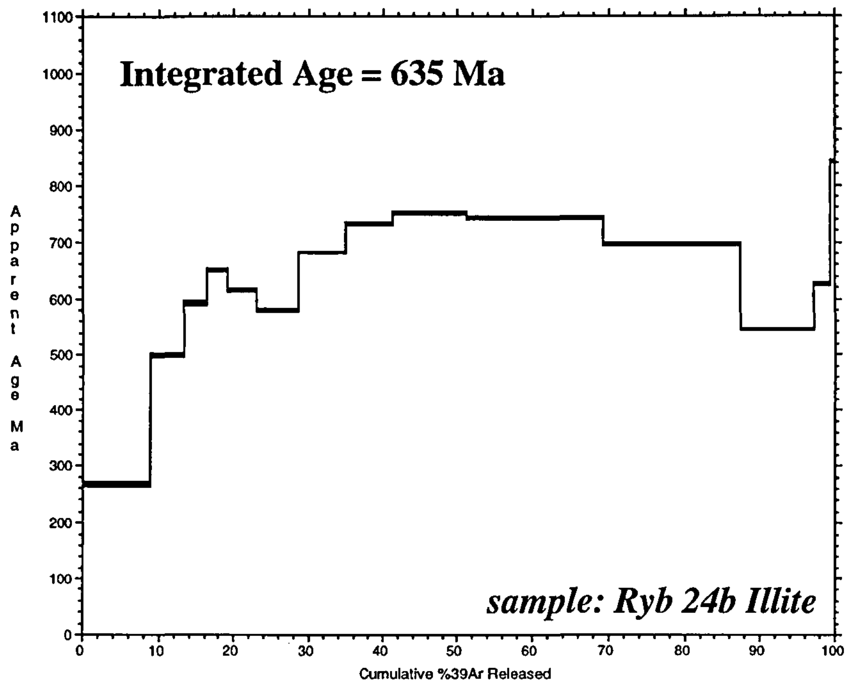
The results of the $^{40}Ar/^{39}Ar$ step-heating experiments are given in Table 1 and Fig. 2. All of the $^{40}Ar/^{39}Ar$ spectra are consistent with mixtures of detrital phyllosilicates and authigenic (neoformed) illite (e.g. Jaboyedoff & Cosca 1999). We have therefore not been able to pinpoint a precise date for the anchizone-grade, pervasive slaty cleavage in these rocks. It is interesting to note that the different spectra show the same general profile form with a high-T 'young' step at c. 80-95%, an 'older' poor plateau at c. 30-70%, and a mini-peak in the profile at c. 10-20%, followed by a 'young' low-T step.

Without additional XRD modelling it is difficult to identify, with any certainty, the relative contributions of the end-members in the mixtures. However, it does appear that the detrital end-member has a maximum age of 850-900 Ma, and the authigenic mica indicates a minimum age of ca. 350-400 Ma. Moreover, it appears that samples Ryb 30 and Ryb 31 yield similar analytical results, 804 and 791 Ma, respectively, and appear to be the least metamorphosed. Samples Ryb 24b and Ryb 32 also have similar analytical behaviour, with integrated total fusion ages of 635 and 652 Ma, respectively, and appear to have the highest concentration of authigenic mica, and could be interpreted as the most strongly metamorphosed samples. Samples Ryb 26 and Ryb 27 yield similar analytical results and give intermediate integrated ages for the two groups just mentioned; 738 and 760 Ma, respectively.

5. DISCUSSION

From the results of this study (Fig. 2, Table 1), it can be concluded that the material analysed does not permit a distinction to be made between the detrital and the authigenic mineral components of these cleaved pelites. The immediate goal of the investigation, i.e., to date the penetrative, inferred Baikalian, metamorphic event, was therefore not achieved. The data, nevertheless, are not without interest.

Field examination of the lithologies and tectonic structures had shown that the most pervasively cleaved pelitic rocks – and thus presumably the ones most strongly metamorphosed -- are those of the two youngest formations in the (north)easternmost parts of the Rybachi Peninsula (Roberts 1995). This observation was largely confirmed by the results of the illite crystallinity investigation, with anchizone in the northeast and upper diagenesis grade in the southwestern parts of Rybachi (Rice & Roberts 1995). The $^{40}Ar/^{39}Ar$ step heating data also show that the two highest, integrated total fusion ages are from the two southwesternmost localities. In these samples, the proportion of detrital illite present was evidently greater than in the higher grade pelite samples in the northeast. Conversely, samples Ryb 24b and 32 in the northeast are showing the greatest tendency towards a weak spectral plateau of all samples



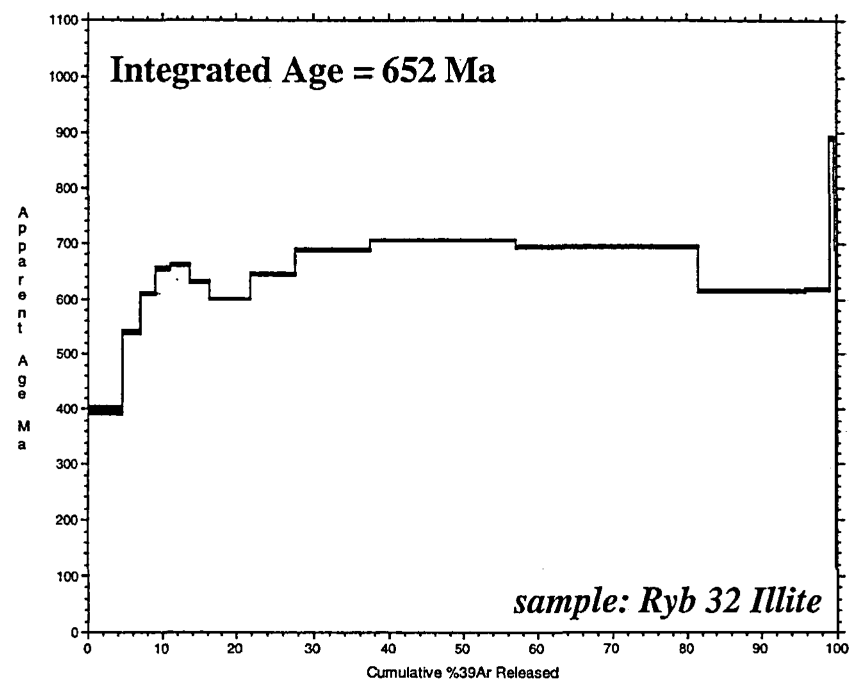
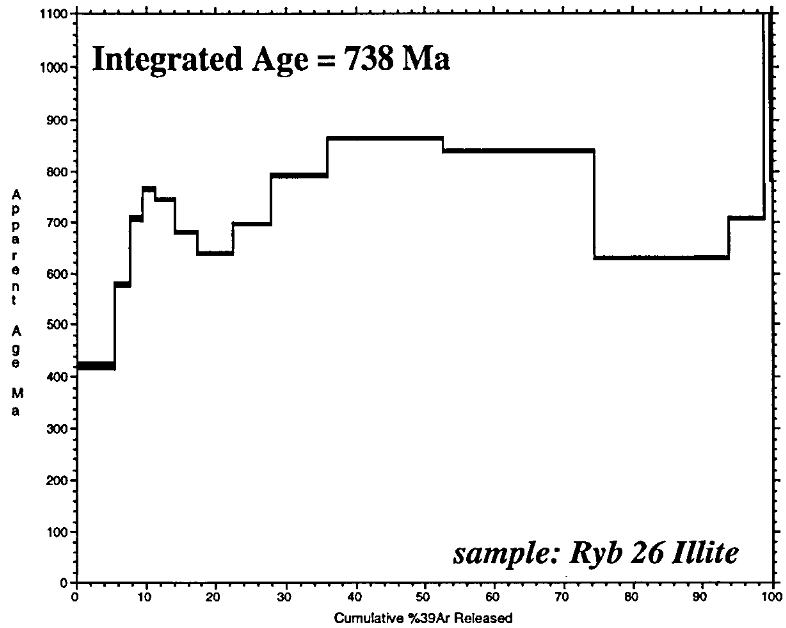
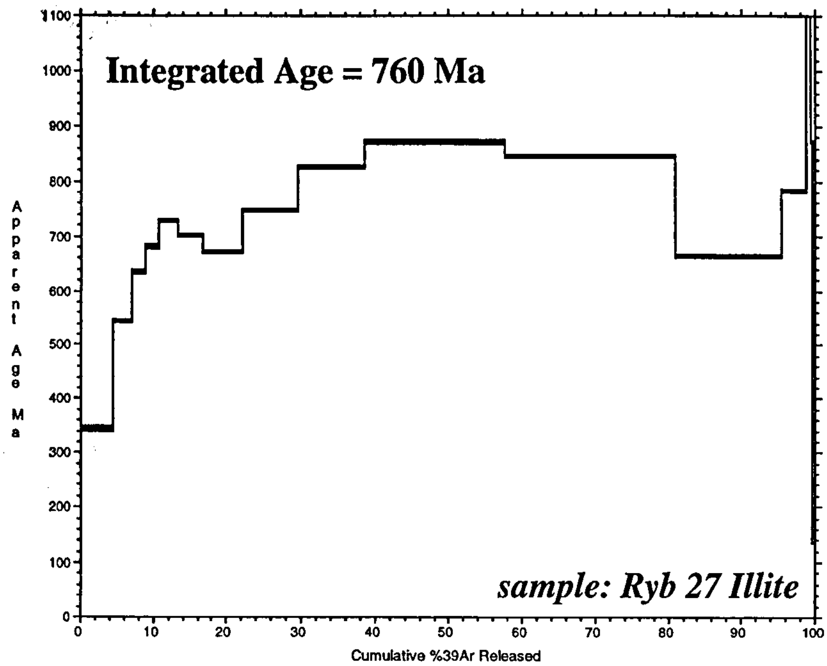


Fig. 2. $^{40}Ar/^{39}Ar$ stepwise degassing spectra for the six samples analysed in this study. The analyses are given in Table 1. Sample localities are shown in Fig. 1.





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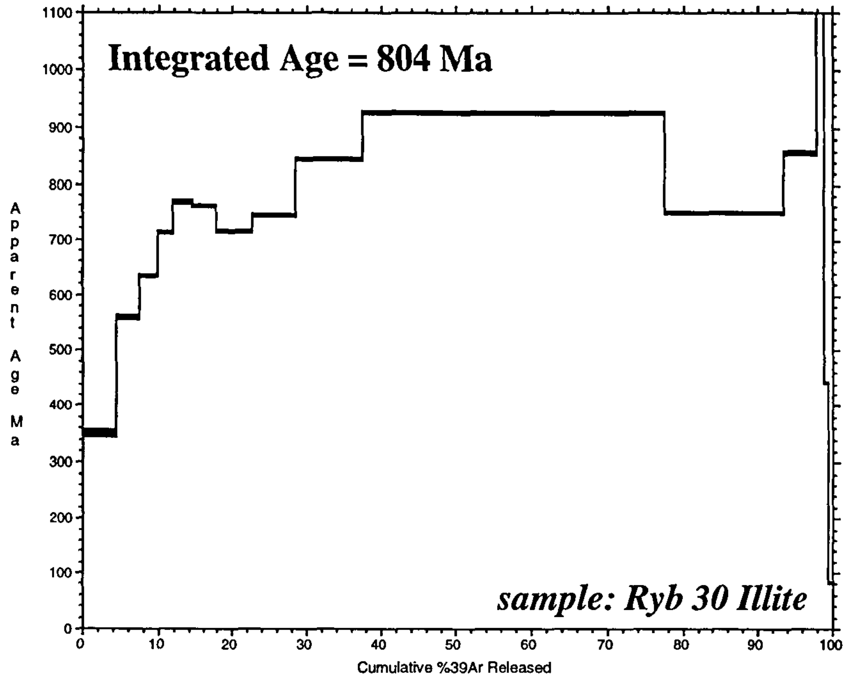

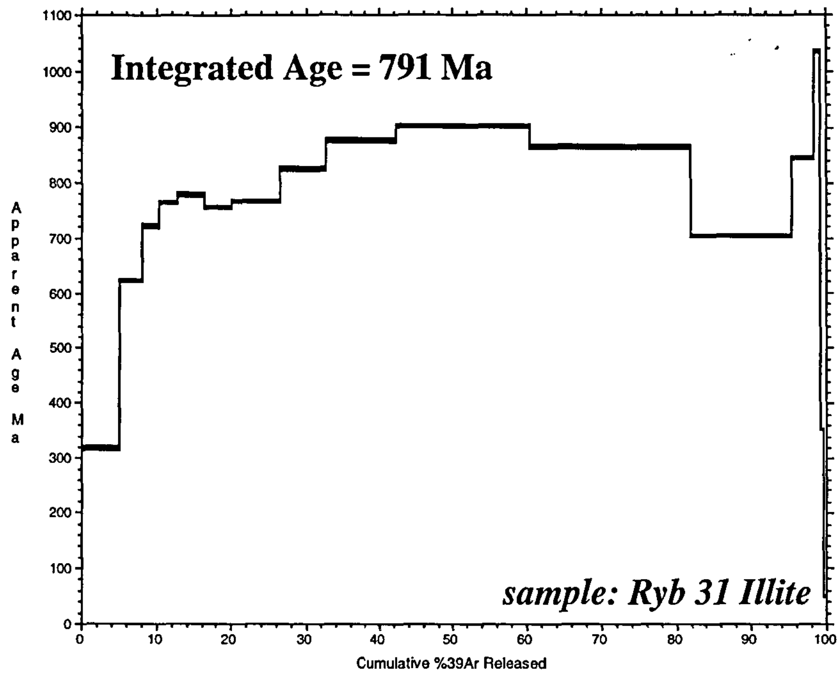

Fig. 2. .... continued.

Table 1. $^{40}Ar/^{39}Ar$ data for the illite samples from pelites from the Rybachi Peninsula.

T (°C)	Ca/K	$^{36}Ar/^{39}Ar$	$^{40}Ar^*/^{39}Ar$	Moles ^{40}Ar (x 10^{-14})	Moles ^{39}Ar (x 10^{-14})	%$^{40}Ar^*$	Age (Ma)	±	1σ
Ryb 30; wt. = 10.28 mg; J = 0.009455 ± 0.5%									
500	1.84	0.13341	22.697	83.8	1.4	36.6	351	±	4
525	2.09	0.03316	38.454	44.4	0.9	79.8	559	±	2
550	2.15	0.03036	44.552	37.2	0.7	83.4	634	±	2
575	1.42	0.03155	51.253	37.5	0.6	84.7	713	±	2
600	1.13	0.02661	56.116	50.5	0.8	87.8	768	±	2
625	0.79	0.01385	55.609	60	1	93.2	762	±	2
650	0.50	0.00834	51.485	82.2	1.5	95.5	716	±	2
675	0.52	0.00660	54.104	103.3	1.8	96.6	745	±	2
700	0.46	0.00532	63.273	184	2.8	97.6	846	±	2
750	0.33	0.00409	70.945	419.1	5.8	98.3	926	±	2
800	0.33	0.00321	70.926	497.4	6.9	98.7	926	±	2
850	0.35	0.00352	54.618	283.9	5.1	98.2	751	±	2
900	0.40	0.00409	64.338	92.6	1.4	98.2	857	±	2
950	0.98	0.00610	98.550	29.6	0.3	98.2	1188	±	3
1000	0.82	0.00588	29.384	7.1	0.2	94.5	442	±	1
1050	0.07	0.00453	4.902	1.2	0.2	78.6	82	±	1
						Integrated total fusion age = 804 Ma			
Ryb 31; wt. = 13.85 mg; J = 0.009455 ± 0.5%									
501	1.47	0.06681	20.461	73.4	1.8	51	319	±	2
525	1.54	0.02566	43.632	58.3	1.1	85.3	623	±	2
550	1.27	0.03586	52.026	49.3	0.8	83.1	722	±	2
575	0.73	0.02627	55.722	62.5	1	87.8	764	±	2
600	0.52	0.01124	57.118	79.3	1.3	94.5	779	±	2
625	0.51	0.00578	54.974	80.8	1.4	97	755	±	2
650	0.31	0.00340	56.011	140.8	2.5	98.3	767	±	2
675	0.31	0.00295	61.318	148.7	2.4	98.6	825	±	2
700	0.26	0.00221	66.172	252.6	3.8	99	877	±	2
750	0.26	0.00156	68.632	487.4	7.1	99.3	902	±	2
800	0.24	0.00118	65.121	541.5	8.3	99.5	866	±	2
850	0.20	0.00123	50.433	266.3	5.2	99.3	703	±	2
900	0.20	0.00174	63.136	76	1.2	99.2	844	±	2
950	0.00	0.00354	81.984	23.5	0.3	98.7	1035	±	3
1000	0.00	0.00530	22.943	4.8	0.2	93.6	354	±	1
1050	0.00	0.00441	3.018	0.6	0.1	69.9	51	±	1
1100	0.00	0.00535	4.013	0.2	0	71.8	67	±	3
						Integrated total fusion age = 791 Ma			
Ryb 32; wt. = 17.41 mg; J = 0.009455 ± 0.5%									
500	0.36	0.13532	26.091	183.6	2.8	39.5	398	±	4
525	0.61	0.04338	36.910	73	1.5	74.3	540	±	2
550	0.42	0.03613	42.498	67.6	1.3	79.9	609	±	2
575	0.29	0.03044	46.223	68	1.2	83.7	654	±	2
600	0.35	0.01757	46.881	82.3	1.6	90.1	662	±	2
625	0.08	0.01061	44.394	72.2	1.5	93.4	632	±	2
650	0.02	0.00684	41.711	146.4	3.3	95.4	600	±	2
675	0.01	0.00552	45.456	171	3.6	96.5	645	±	2
700	0.00	0.00431	49.039	306.3	6.1	97.5	687	±	2
750	0.11	0.00308	50.636	629.1	12.2	98.2	706	±	2
800	0.13	0.00223	49.634	762.5	15.2	98.7	694	±	2
850	0.12	0.00251	43.008	390.8	8.9	98.3	616	±	2
900	0.01	0.00337	43.184	88.8	2	97.7	618	±	2
950	0.00	0.00523	67.463	25.4	0.4	97.8	890	±	2
1000	0.00	0.01008	49.405	6.3	0.1	94.3	692	±	2
1050	0.00	0.01193	6.987	0.9	0.1	66.5	115	±	1
1100	0.00	0.01134	2.886	0.3	0	46.4	49	±	2
						Integrated total fusion age = 652 Ma			

Table 1. .... continued.

Ryb 24b; wt. = 11.10 mg; J = 0.009455 ± 0.5%

500	0.94	0.06890	16.841	91.7	2.5	45.3	267	±	2
525	0.76	0.03318	33.781	53.4	1.2	77.6	500	±	2
550	0.00	0.03484	41.109	39.9	0.8	80	592	±	2
575	0.00	0.02863	45.833	42.8	0.8	84.4	650	±	2
600	0.00	0.01374	43.011	51.2	1.1	91.4	616	±	2
625	0.00	0.00710	40.106	66.8	1.6	95	580	±	2
650	0.00	0.00555	48.528	90.8	1.8	96.7	681	±	2
675	0.00	0.00473	52.989	97.7	1.8	97.4	733	±	2
700	0.00	0.00374	54.658	159.3	2.9	98	752	±	2
750	0.00	0.00283	53.933	285.1	5.2	98.5	743	±	2
800	0.00	0.00216	49.865	264.9	5.2	98.7	697	±	2
850	0.00	0.00221	37.398	110.4	2.9	98.3	546	±	2
900	0.00	0.00299	43.850	28	0.6	98	626	±	2
950	0.00	0.00152	63.030	10.4	0.2	99.3	843	±	2

Integrated total fusion age = 635 Ma

Ryb 27; wt. = 13.07 mg; J = 0.009455 ± 0.5%

500	1.74	0.09570	22.243	91.9	1.8	44.1	344	±	3
525	1.22	0.03493	37.262	51.8	1.1	78.4	545	±	2
550	0.25	0.03368	44.624	41.4	0.8	81.8	635	±	2
575	0.00	0.03221	48.574	40.8	0.7	83.6	682	±	2
600	0.00	0.01949	52.579	67.2	1.2	90.1	728	±	2
625	0.00	0.01109	50.372	77.9	1.5	93.9	703	±	2
650	0.00	0.00738	47.832	112.6	2.3	95.6	673	±	2
675	0.00	0.00581	54.421	181.9	3.2	96.9	749	±	2
700	0.00	0.00481	61.530	243.3	3.9	97.7	827	±	2
750	0.06	0.00364	65.633	542.5	8.1	98.4	871	±	2
800	0.05	0.00287	63.303	646	10.1	98.7	846	±	2
850	0.00	0.00372	46.970	299.9	6.2	97.7	663	±	2
900	0.00	0.00459	57.546	86.9	1.5	97.7	784	±	2
950	0.00	0.00581	111.220	31.8	0.3	98.5	1296	±	3
1000	0.00	0.00522	65.781	9.2	0.1	97.7	873	±	2
1050	0.00	0.00220	8.252	1.4	0.2	92.7	136	±	1

Integrated total fusion age = 760 Ma

Ryb 26; wt. = 12.44 mg; J = 0.009455 ± 0.5%

500	0.90	0.11636	27.867	102.7	1.6	44.8	422	±	3
525	0.58	0.05671	39.926	39.1	0.7	70.5	578	±	2
550	0.00	0.06544	50.755	35.7	0.5	72.4	707	±	3
575	0.00	0.04838	55.996	39.3	0.6	79.7	767	±	3
600	0.00	0.02703	54.048	51.5	0.8	87.1	745	±	2
625	0.00	0.01811	48.329	53.4	1	90	679	±	2
650	0.00	0.01271	44.914	78	1.6	92.3	639	±	2
675	0.00	0.01013	49.890	88.9	1.7	94.3	697	±	2
700	0.00	0.00812	58.330	153.7	2.5	96	792	±	2
750	0.00	0.00556	64.988	348.8	5.2	97.5	864	±	2
800	0.00	0.00395	62.692	435.8	6.8	98.2	840	±	2
850	0.00	0.00763	44.003	281.2	6.1	95.1	628	±	2
900	0.00	0.00816	50.864	81	1.5	95.5	708	±	2
950	0.00	0.00425	101.459	30.5	0.3	98.8	1213	±	3
1000	0.00	0.00319	57.544	6.8	0.1	98.4	784	±	2

Integrated total fusion age = 738 Ma

analysed, and at the same time have yielded the youngest integrated ages, indicating the likely presence of a higher proportion of authigenic, metamorphic illite.

In a Rb-Sr dating study of multistage illite generation in shales from the Sredni Peninsula, Gorokhov et al. (1995) noted that their coarsest subfractions, between c. 2 and 5 μm, gave ages greater than 800 Ma – detrital illites inherited from the provenance area. This age is not unlike the maximum age of the detrital end-members in the mixtures in the present study, i.e., 850-900 Ma. In a comparable Rb-Sr illite dating study from the Varanger Peninsula in Norway, the coarsest subfraction (1-2 μm) in one sample yielded a minimum age for this detrital component of >900 Ma.

One further aspect of interest in the $^{40}Ar/^{39}Ar$ data reported here relates to the low-T increment in the gas-release spectra, in the range 350 to 400 Ma. This minimum age applies to an assumed authigenic illite component. Without going into detailed discussion, this Mid Devonian-Early Carboniferous age is comparable to the $^{40}Ar/^{39}Ar$ mineral isochron, thermal overprint ages (401-373 Ma) generated from mafic dykes cutting the Rybachi metasedimentary rocks (Roberts & Onstott 1995). These authors ascribed these dates as relating to a resetting by a low-grade thermal event associated with a period of regional rifting and sedimentation. Similar, U-Pb zircon, lower intercept ages recorded widely in northern Fennoscandia have been interpreted in much the same way, i.e., as recording a partial resetting of the isotope systems during a Caledonian event (Levchenkov et al. 1995); or crustal extension and the thermal influence of burial by an originally thick and widespread Devono-Carboniferous sedimentary cover in this region (Roberts et al.1997, Larsen & Tullborg 1998). Rocks of this age are present beneath a Mesozoic and younger cover in the southern parts of the Barents Sea, as well as farther east beneath the Pechora Basin.

6. CONCLUSIONS

$^{40}Ar/^{39}Ar$ step-heating analyses carried out on Neoproterozoic, anchizone-grade, cleaved pelites from the Rybachi peninsula, Kola, Northwest Russia, were not definitive in terms of trying to date the pervasive, syn-folding metamorphic event. Spectra from all six samples are consistent with mixtures of detrital phyllosilicates and authigenic illite. In general, the highest, integrated total fusion ages are from diagenesis-grade rocks in the southwestern part of Rybachi. Conversely, the lowest total fusion ages are from samples from anchizone-grade rocks in the northeast. These show weak spectral plateaux, indicating that authigenic, metamorphic illite is more dominant in these particular samples.

The detrital end-members in the mixtures appear to have a maximum age of 850-900 Ma. This age is similar to that generated from detrital grains in a Rb-Sr study of illites from shales on the neighbouring Sredni Peninsula, and also from the Varanger Peninsula in Norway. The lowtemperature increment in the gas-release spectra falls in the range 350-400 Ma, an age which is comparable to $^{40}Ar/^{39}Ar$ mineral isochron, thermal overprint ages (373-401 Ma) from dolerite dykes cutting cleaved shales on Rybachi. These low-T dates may be ascribed to the thermal influence of burial by an originally thick and widespread cover of Upper Devonian-Carboniferous sedimentary rocks in this and adjacent regions of NW Russia and the southern Barents Sea.

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